Clean Copy of All Pending Claims

1   1. (Amended) A method for modifying a voxel-based virtual object in a haptic virtual

2   environment, comprising:

3   determining a virtual tool comprising a plurality of discrete points for use by the user in

4   the haptic virtual environment;

5   selecting a modification mode that modifies a voxel value representative of the voxel-

6   based virtual object;

7   sensing a location of a user in real space;

8   determining locations of the plurality of discrete points of the virtual tool relative to a

9   location of the voxel-based virtual object;

10   calculating an interaction force between the virtual tool and the voxel-based virtual

11   object based on the locations of the plurality of discrete points of the virtual tool and the

12   location of the voxel-based virtual object;

13   producing a modified voxel-based virtual object by modifying the voxel-based virtual

14   object based on the modification mode, the locations of the plurality of discrete points of the

15   virtual tool, and the location of the voxel-based virtual object; and

16   outputting the modified voxel-based virtual object.

1   2. (Amended) The method of claim 1, further comprising the steps of

2   determining a virtual surface for the voxel-based virtual object; and

3   determining a position and an orientation of the virtual tool by determining the locations

4   of the plurality of discrete points relative to the virtual surface of the voxel-based virtual object.

1   3. (Amended) The method of claim 2, wherein the step of determining the virtual surface

2   comprises determining a virtual isosurface for the voxel-based virtual object.

1   4. (Amended) The method of claim 1, wherein the voxel-based virtual object is a volumetric

2   representation.

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1 5. The method of claim 4, wherein the volumetric representation comprises voxels comprising

2 density values.

1 6. (Twice Amended) The method of claim 1, wherein the step of selecting a modification mode

2 comprises selecting at least one of a material removal mode, a material addition mode, a

3 smoothing mode, a mirroring mode, and a 3-D sketch mode.

1 7. The method of claim 1, further comprising the step of determining at least one virtual

2 constraint for the movement of the virtual tool.

1 8. The method of claim 7, wherein the step of determining at least one virtual constraint for the

2 movement of the virtual tool comprises determining at least one of a point, curve and surface

3 constraint for the movement of the virtual tool.

1 9. (Amended) The method of claim 1, further comprising the step of exporting the modified

2 voxel-based virtual object.

1 10. (Twice Amended) A system for modifying a voxel-based virtual object by a user in a haptic

2 virtual environment, the system comprising:

3 a virtual tool comprising a plurality of discrete points for use by the user in the haptic

4 virtual environment, wherein the user selects a modification mode that modifies a voxel

5 value representative of the voxel-based virtual object;

6 a haptic interface device, wherein the haptic interface device senses a location of the user

7 in real space; and

8 a modeling application in communication with the haptic interface device, the voxel-

9 based virtual object, and the virtual tool, wherein the modeling application determines

10 locations of the plurality of discrete points of the virtual tool relative to a location of the

11 voxel-based virtual object; calculates an interaction force between the virtual tool and the

12 voxel-based virtual object based on the locations of the plurality of discrete points of the

13 virtual tool and the location of the voxel-based virtual object; produces a modified voxel-

14 based virtual object by modifying the voxel-based virtual object based on the modification

15 mode, the locations of the plurality of discrete points of the virtual tool, and the location of

16 the voxel-based virtual object; and outputs the modified voxel-based virtual object.

1 11. (Amended) The system of claim 10, further comprising

2 the voxel-based virtual object comprising a virtual surface; and

3 the virtual tool comprising a position and an orientation, wherein the modeling

4 application determines the position of the virtual tool and the orientation of the virtual tool by

5 determining the locations of the plurality of discrete points relative to the virtual surface of the

6 voxel-based virtual object.

1 12. (Amended) The system of claim 11, wherein the virtual surface of the voxel-based virtual

2 object is a virtual isosurface.

1 13. (Amended) The system of claim 10, wherein the voxel-based virtual object is a volumetric

2 representation.

1 14. The system of claim 13, wherein the volumetric representation comprises voxels comprising

2 density values.

1 15. (Amended) The system of claim 10, wherein the modification mode is a selected one of a

2 material removal mode, a material addition mode, a smoothing mode, a mirroring mode, and a 3-

3 D sketch mode.

1 16. The system of claim 10, wherein the user determines at least one virtual constraint for a

2 movement of the virtual tool.

1 17. The system of claim 16, wherein the at least one virtual constraint for the movement of the

2 virtual tool is at least one of a point, curve and surface constraint.

1 18. (Amended) The system of claim 10, wherein the modeling application exports the modified

2 voxel-based virtual object.

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1   19. (Amended) A method for interfacing with a voxel-based virtual object in a haptic virtual

2   environment, comprising:

3   generating a voxel-based virtual object comprising a virtual surface in the haptic virtual

4   environment;

5   setting a constraint geometry in the haptic virtual environment;

6   determining a virtual tool for use by the user in the haptic virtual environment;

7   sensing a location of a user in real space;

8   determining a haptic interface location in the haptic virtual environment in response to

9   the location of the user in real space;

10   determining a position of the virtual tool in the haptic virtual environment in comparison

11   to the haptic interface location and the location of the virtual surface and the constraint geometry;

12   constraining an action of the virtual tool based on (i) the constraint geometry, (ii) the

13   virtual surface, (iii) the position of the virtual tool, and (iv) the haptic interface location.

1   20. The method of claim 19, wherein the step of setting a constraint geometry comprises setting

2   at least one of a constraint point, constraint curve, and a constraint surface.

1   21. The method of claim 19, wherein the step of determining the position of the virtual tool

2   further comprises moving the position of the virtual tool to coincide with the haptic interface

3   location.

1   22. (Amended) The method of claim 19, further comprising the step of modifying the voxel-

2   based virtual object based on the position of the virtual tool.

1   23. (Amended) The method of claim 19, further comprising calculating an interaction force

2   among the constraint geometry, the voxel-based virtual object, and the virtual tool in response to

3   the step of determining the position of the virtual tool.

1   24. (Twice Amended) The method of claim 19, further comprising the steps of selecting a

2   modification mode that modifies a voxel value representative of the voxel-based virtual object,

3   and modifying the voxel-based virtual object in response to the modification mode and the

4   position of the virtual tool.

1   25. The method of claim 19, wherein the step of constraining the action of the virtual tool

2   comprises constraining the translation of the virtual tool.

1   26. The method of claim 19, wherein the step of constraining the action of the virtual tool

2   comprises constraining the rotation of the virtual tool.

1   27. (Amended) A system for interfacing with a voxel-based virtual object in a haptic virtual

2   environment, the system comprising:

3   a voxel-based virtual object comprising a virtual surface;

4   a virtual tool for use by the user in the haptic virtual environment;

5   a constraint geometry limiting the movement of the virtual tool in the haptic virtual

6   environment;

7   a haptic interface device, wherein the haptic interface device senses a position of the user

8   in real space;

9   a modeling application in communication with the haptic interface device, the voxel-

10 based virtual object, and the virtual tool, wherein the modeling application determines a haptic

11 interface location in the haptic virtual environment in response to the location of the user in real

12 space; determines a position of the virtual tool in the haptic virtual environment in comparison to

13 the haptic interface location, and the location of the virtual surface and the constraint geometry;

14 and constraining an action of the virtual tool based on (i) the constraint geometry, (ii) the virtual

15 surface, and (iii) the position of the virtual tool, and (iv) the haptic interface location.

1   28. The system of claim 27, wherein the constraint geometry is at least one of a constraint point,

2   constraint curve, and a constraint surface.

1   29. The system of claim 27, wherein the modeling application determines the position of the

2   virtual tool by moving the position of the virtual tool to coincide with the haptic interface

3   location.

1   30. (Amended) The system of claim 27, wherein the modeling application modifies the voxel-

2   based virtual object based on the position of the virtual tool.

1   31. (Amended) The system of claim 27, wherein the modeling application calculates an

2   interaction force among the constraint geometry, the voxel-based virtual object, and the virtual

3   tool in response to determining the position of the virtual tool.

1   32. (Twice Amended) The system of claim 27, further comprising a modification mode that

2   modifies a voxel value representative of the voxel-based virtual object, and the modeling

3   application modifies the voxel-based virtual object in response to the modification mode and the

4   position of the virtual tool.

1   33. The system of claim 27, wherein the action of the virtual tool comprises a translation of the

2   virtual tool.

1   34. The system of claim 27, wherein the action of the virtual tool comprises a rotation of the

2   virtual tool.

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